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FROM MISSILES TO SPACE:
THE JET PROPULSION LABORATORY, 1955-1960

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WINDOW TO SPACE: EXPLORERS AND PIONEERS

While most of JPL's research and development activities in the 1940s and 1950s were devoted to terrestrial problems, space had never been far from the minds of the laboratory's scientists and engineers. Frank Malina and Martin Summerfield had calculated in 1945 that it was possible to build a rocket that would "escape earth's atmosphere." In 1949 the Bumper WAC, a WAC Corporal mounted on a V-2, had set an altitude record by ascending 250 miles; it had also proved the feasibility of rockets operating in stages. Passing the time between test flights at White Sands, New Mexico, in 1950, some JPL engineers scribbled back-of-the-envelope calculations that showed it was possible to cluster some Loki rockets on a Corporal missile and land an empty beer can on the moon. More seriously and certainly more formally, JPL director William Pickering was active throughout the 1940s and 50s on the Upper Atmosphere Research Panel, which sponsored research using high-altitude sounding rockets.[1]

Earth-orbiting satellites, whose principles had been known since Isaac Newton, had approached technical feasibility with the development of rocketry during World War II. Any object set moving outside the earth in a proper direction and at a proper speed will travel around the earth in an elliptical orbit, where centrifugal force exactly balances the pull of gravity. The first requirement for orbiting a satellite was attaining the proper speed. Intercontinental missiles attained speeds of about four miles per second and went out into space about 800 miles before falling back to earth. Satellites required a speed of five miles per second. (To escape the earth's gravitational field and travel to the moon required an initial speed of seven miles per second, planetary flights only a little more.) Some scientists at the RAND Corporation and the Navy had proposed building satellites in the late 1940s. By 1954, as the United States initiated a crash program to develop intercontinental ballistic missiles, and the scientific and military uses of satellites became apparent, satellite proposals neared the hardware stage.[2]

Scientists won approval for a satellite as a United States contribution to the International Geophysical Year coming up in 1957-1958. JPL became involved in the venture when the Army Ballistic Missile Agency and the Office of Naval Research sent their proposal for the joint effort, Project Orbiter, to Pasadena for review in late 1954. Orbiter's first stage would be an uprated Redstone missile. The remaining stages would consist of Lokis, the small solid-propellant antiaircraft rockets developed at JPL; the second stage would use 24 Lokis; the third, six; and the fourth, one Loki and the five-pound payload. JPL reviewers recommended against the use of Lokis because the failure of any one of the 31 rockets could prevent the satellite from attaining orbit. Homer J. Stewart, the Caltech aerodynamics professor who also supervised systems analysis at JPL, recommended instead that Orbiter use a smaller number of the more powerful and more reliable Sergeant rocket motors, scaled down from 31 inches in diameter to six inches in diameter. Revised in accordance with Stewart's ideas, the Orbiter proposal appeared headed for smooth sailing in early 1955.[3]

But Stewart, ironically, had to preside over the demise of the ABMA-ONR-JPL proposal. Stewart chaired the Ad Hoc Committee on Special Capabilities, a subgroup of the Department of Defense Guided Missiles Committee, which was formed to referee the competition between the Orbiter and Vanguard, a dark-horse entry from the Naval Research Laboratory. Orbiter's strength lay in its powerful rocket motors and proven technology, which made possible a launch by August 1957, and probably earlier. Vanguard, by contrast, utilized a smaller rocket, the Viking, which was still under development. But the original Vanguard proposal demonstrated superior electronics technology, which could return more sophisticated scientific data; the original Orbiter had proposed only optical tracking. JPL and ONR scrambled to beef up Orbiter's tracking and telemetry components, but too late. The committee split over differing technical judgments, interservice rivalries, and concern for a "peaceful" rocket instead of an adaptation of a military missile -- and one designed by Germans at that. The two Army-designated committeemen, Stewart and Clifford C. Furnas, chancellor of the State University of New York at Buffalo, strongly supported Orbiter. But the Stewart Committee voted six to two in August 1955 to make Vanguard the first American satellite program. When the Soviet Sputnik upstaged Vanguard while Orbiter waited in the wings, the decision became one of the most controversial of the space age.[4]

JPL and the other Orbiter backers chafed under the decision and tried repeatedly to get it reversed. The laboratory contributed several more sophisticated electronics studies, but Orbiter remained moribund. Yet through personal and institutional connections in the communications aspects of missilery, JPL remained near the center of action. Pickering was a member of the Technical Panel for the Earth Satellite Program that was organized by the United States IGY committee in October 1955, and he chaired the working group on tracking and computation. The JPL director thus found himself in the anomalous position of promoting a competing technical proposal but organizing operational support for Vanguard.[5]

JPL and ABMA found an institutional outlet for their Orbiter studies in the Re-Entry Test Vehicle, which, by a circuitous course, eventually led to the first American space triumph. ABMA, led by Wernher von Braun and Major General John B. Medaris, was developing the Jupiter, a medium-range ballistic missile that was engaged in a notorious competition with the Air Force's Thor. To counteract the terrific heat the Jupiter encountered as it reentered the atmosphere at high velocity, ABMA planned to use a blunt ablation-type nose cone, in which the various layers peeled away during reentry. The Jupiter was extraordinarily similar to Orbiter; in fact, the missile needed only the fourth-stage booster rocket and payload to create a satellite. JPL's Orbiter electronics proposals therefore proved readily adaptable to the Jupiter program. The laboratory's telemetry could send data back to ground control on the heating effects of the missile during flight, and its tracking mechanism made it possible to recover the nose cone at the end of the flight.[6]

The main JPL contribution was Microlock, a phased-locked loop tracking system. The innovation in Microlock was its ability to lock to a very low-level signal; under ideal conditions it could lock on a signal as low as a milliwatt nearly 6000 miles away. The origins of

Microlock could be traced to some of the early guidance and information theory research for the Corporal. Researching the high-frequency properties of transistors, JPL engineers discovered they operated well but could put out only fifty microwatts. Such low power at first seemed to be useless, but paper calculations followed by experiments demonstrated that, if an appropriate phase-locked receiver were used, the signal might be received from as far as 1000 miles in free space transmission. As adapted for the RTV, Microlock would also extract information from five minimum-weight telemetry channels. Microlock was an interesting example of how advances in hardware sometimes led to a string of conceptual innovations.[7]

The RTV also incorporated JPL's skills with solid propellant motors in the delicate positioning of the upper stages. The eleven motors of the second stage were mounted in an annular ring inside a tub, the three motors of the third stage fit inside the second stage, and the fourth-stage motor and payload sat in the center of the two outer rings. When each stage fired it broke the shear pins that attached it to the previous assembly and let that stage fall back to earth. For greater accuracy the upper stages were enclosed in a spinning tub that was powered by two battery-driven electric motors. The tub began spinning at 550 rpm before takeoff; about 70 seconds into the flight the speed gradually increased to about 750 rpm. This procedure eliminated "resonance between the spin frequency and the natural bending frequencies of the missile," which increased as the first-stage propellants were consumed. The spinning tub imposed severe vibration and centrifugal force on the second stage. Extensive ground testing under simulated flight conditions showed the motors performed well, but small changes in the nozzle design were necessary. Throughout the design of the upper stages highly accurate positioning and balance were necessary to curb vibration and deflection.[8]

The lash-up seemed somewhat "Rube Goldbergish," in the words of Eisenhower's second science advisor, George Kistiakowsky of Harvard University; but it worked. The first Jupiter C missile* in the RTV series was fired on September 20, 1956, from Cape Canaveral, Florida. Some Pentagon officials watched nervously because they feared the RTV was a ruse for a clandestine satellite launching. The first RTV set records for American missiles to that point: an altitude of 682 miles and a distance of 3350 miles. All the test objectives were met. The motor demonstrated the desired power, the aerodynamic design worked satisfactorily, and the Microlock system performed very close to theory. Since the Army was interdicted from attempting a satellite, the fourth stage was loaded with sandbags. Had the RTV contained a small Sergeant

* If the nomenclature of Redstone, Jupiter A and C, RTV, Orbiter, and Explorer seemed confusing, it was traceable partly to bureaucratic sleight-of-hand missile rivalry of the mid-1950s. From JPL's standpoint in space the salient point was that the RTV, Orbiter, and Explorer, though sometimes called Jupiter C, all used the Redstone missile plus upper stages composed of scaled Sergeant motors. (JPL was also working on the radio-inertial guidance system for the MRBM Jupiter, but this program was largely separate from the space activities.) The confusing terminology arose because the Army was anxious to test Jupiter components before the missile itself was ready in May 1957. ABMA simply put the components on the smaller Redstone missiles and hung the label "Jupiter A" on them because Jupiters had higher priorities for launching at Cape Canaveral. The RTV was not a true Jupiter either, but a Redstone plus upper stages with Sergeant motors; the RTV composite vehicle Medaris labeled "Jupiter C." (Medaris, Countdown for Decision, p. 119).

motor for just a little extra kick, JPL and ABMA would have put a satellite in orbit -- a year before the Soviet Union.[9]

In the second RTV test, May 15, 1957, the missile took an erratic course because of a guidance malfunction shortly before the fuel cutoff. The nose cone was tracked to its point of impact but was not recovered. (The missilemen suspected sharks beat them to the cone since on some subsequent tests jaws had ripped open the balloons that kept the cones afloat.) The third firing, on August 8, 1957, succeeded brilliantly. All major systems worked satisfactorily, and the nose cone was recovered at a range of 1160 miles. The ablation-type nose cone proved superior to other techniques and was subsequently adopted in the other American missiles. The design of the Jupiter had been validated, and the tests ended with several sets of flight hardware in various stages of fabrication left over. Indeed, the successful culmination of the program appeared to thwart the efforts of ABMA and JPL personnel, particularly Homer Stewart, who wanted to keep the RTV series going as a backup to a Vanguard they expected to fail. With the RTV terminated, ABMA and JPL did the next best thing. Medaris and von Braun put the extra hardware in controlled storage, from which it could be made flight-ready in less than four months for "more spectacular purposes." JPL Jupiter project manager Jack Froehlich assigned the remaining Sergeant scale motors to long-term life test, which had the same effect.[10]

As the RTV series concluded in the summer of 1957, JPL found itself in a period of self-analysis and frustration. The Sergeant missile program was moving along well but more weapons projects were unattractive to JPL. Fearing that JPL might become just a "job shop" for the Army, Pickering and Caltech President Lee DeBridge had agreed in 1954 that the Sergeant would be the laboratory's last major weapons development. The radio-inertial guidance program the laboratory had undertaken on Jupiter ranked as a backup to a backup in an interim development. Satellites seemed the best new direction for JPL. As Pickering noted in mid-1957, "the whole trend of rocketry is in this area." The problem for the Pasadenans was to "find the right way to begin." That seemed to mean working through the Army, but the Air Force's lock on military satellite planning to that point seemed to leave the Army with only the marginal activity of reconnaissance satellites limited to tactical uses. Indicative of the uncertainty at the laboratory, as late as the summer of 1957 it seemed that primary attention over the next three years should be given to extending the RTV flights. Then, on Friday night, October 4, 1957, JPL personnel scattered across the country discovered that a red light was orbiting the earth and that its name was Sputnik, Russian for fellow-traveler.[11]

* * * * *

Pickering had gone to Washington D.C. five days earlier for a week of IGY meetings. On Monday he had heard a Russian scientist announce that the USSR would launch a satellite "in the near future," as the translator rendered the phrase; but an American scientist who knew Russian leaned over to Pickering and whispered, "That's not what he said -- he said 'imminent.'" Even so, the JPL director was not prepared for what he heard at a party at the Soviet embassy the night of October 4. Walter Sullivan, the New York Times science writer, bustled into the room and asked him what he knew about the satellite

the Russians said they had just launched. It was the first that Pickering -- and probably anyone else in the room, including the Russians -- knew about Sputnik. Pickering hurriedly conferred with several other persons, including Lloyd Berkner, who hushed the room and proposed a toast. Amid successive torrents of celebratory vodka and caviar, Pickering and his IGY colleagues slipped out to the IGY offices a few blocks away. There they pieced together what information they could to see whether Sputnik really was in orbit, calculated when it would pass over New York, relayed the information to the press, and went to sleep -- only to be awakened after an hour when their calculations proved mistaken, and they had to recalculate the time of passage and call the press again. It was a long night that left indelible impressions. JPL personnel could remember years later where they were when they heard the news, what they first thought, and what they did, much as other people could recall how they felt when they heard of the deaths of presidents or of the bombing of Pearl Harbor.[12]

The night of Sputnik I von Braun and Medaris were chatting with the new secretary of defense, Neil McElroy, who by coincidence was visiting Huntsville. "Vanguard will never make it," cried von Braun. "We have the hardware on the shelf. For God's sake turn us loose and let us do something. We can put up a satellite in sixty days, Mr. McElroy! Just give us a green light and sixty days'" As von Braun kept repeating "sixty days," Medaris cautioned: "No, Wernher, ninety days." McElroy returned to Washington noncommital.[13]

The Eisenhower administration took the news of Sputnik in stride. At his first meeting to consider a response to the Russian satellite, on October 9, the president asked Quarles if it was correct that the United States could have orbited a satellite more than a year earlier by using a Redstone. Quarles said yes. But Vanguard had two advantages, he continued. It stressed the "peaceful character of the effort" and it avoided "the inclusion of material, to which foreign scientists might be given access, which is used in our own military rockets." The Army still felt it could launch a satellite within four months, a month earlier than Vanguard. Eisenhower demurred. The need for military classification of the rocket still impressed him. The satellite had been tied to the IGY and had never been a crash program, he recalled. "To make a sudden shift in our approach now would be to belie the attitude we have had all along," he pointed out. The administration soon agreed to advance Vanguard's first launch date, and on October 31 the general cautiously accepted McElroy's suggestion to use the Army backup to Vanguard. Eisenhower also beefed up his science advisory system by appointing his first advisor on science and technology, James R. Killian, Jr., president of the Massachusetts Institute of Technology. On November 8 Eisenhower delivered a nationally televised address designed to reassure citizens that their security was not endangered and that the presumed humiliation of Sputnik was only temporary. Among his props was the recovered nose cone from the ABMA-JPL Re-entry Test Vehicle.[14]

Public opinion showed a mixture of alarm and concern, apathy and calm. But in Congress, the military, and the scientific and technical communities a storm of recrimination was breaking. "We do not have as much time as we did after Pearl Harbor," said Senator Lyndon B. Johnson, Democrat of Texas. The hysteria over Sputnik represented

varying proportions of wounded pride, a domestic political weapon, a genuine international challenge, and an opportunity for promoting institutions' projects of self-interest. Brig. Gen. Homer Boushey, who had piloted the plane bearing the first JPL JATOs in 1940, and was now deputy director of Air Force research and development, warned: "Who controls the moon controls the earth." Pickering remarked sourly: "It is pretty obvious that very few people in this country had any appreciation of the political significance of the Russian satellite," and that included the politicians "in a position to make decisions." It was an "obvious fact" that the Russians were "well ahead" in weapons technology, he continued. To "recover national prestige" the United States did not need dramatic scientific breakthroughs but "good management and good engineering on programs which already exist." Not coincidentally, this meant using the capabilities of ABMA and JPL on Jupiter, and perhaps on a more daring attempt to leapfrog the Russians.[15]

The laboratory staff hastily drew up Project Red Socks, a plan to launch nine rockets to the moon in great haste. The laboratory used the full cachet of its parent in the proposal, dated October 25, 1957: "The California Institute of Technology believes that it is essential for the United States to initiate an immediate program for the scientific exploration of the moon." Sputnik implied the Russians could send flights to the moon, said the proposal. "National interest appears to require the United States to demonstrate as soon as possible that U.S. science likewise has this capability." The first rocket, which would use the RTV hardware, would be scheduled for June 1958 and send 15 pounds around the moon. The remaining eight flights would consist of scaled-up RTV equipment and send 120-pound payloads to the moon from January 1959 through the end of 1960. The first flight would carry instruments to measure temperature, pressure, and light intensity. The remaining flights would expand on these experiments, and the last several rounds might incorporate more sophisticated guidance to refine the orbit around the moon. In the quest for spectacular science, JPL officials flirted with even bolder ideas. Pickering and other scientists toyed with the idea of exploding an atomic bomb on the lunar surface, which would "shower the earth with samples of surface dust in addition to producing beneficial psychological results."[16]

These schemes seemed audacious, even bizarre, for a space program that had yet to get off the ground. Pickering and DuBridge peddled the Red Socks proposal through the corridors of the Pentagon. Lieutenant General James Gavin, head of Army research and development, liked it immensely and told the Californians he would consider its approval the crowning achievement of his career. Donald Quarles, assistant secretary of defense for research and development, seemed interested, but he wanted to involve the Air Force. Back in the corridor, Pickering turned to DuBridge and said, "Well, that kills that." Red Socks never got into the race.[17]

Through October and November, however, the pressure built for Jupiter. A few days after Sputnik I, the audacious Medaris told the crews at ABMA to take the RTV hardware out of storage and begin readying it for launch. Medaris lacked higher authority for this action; in fact he issued his instructions at the same time the president reaffirmed his intention to stick with the nonmilitary approach. Medaris figured the

amount of money was relatively small and that he could bury it somewhere, if necessary. He was banking, too, on the long-held conviction in Army-JPL circles that Vanguard would falter. The Soviet Union bolstered his plans when, on November 3, it orbited Sputnik II with a dramatic payload: 1100 pounds in weight and a live dog, Laika. On November 8 the Department of Defense at last gave the Army and JPL authorization to prepare their satellite. Explorer, as Orbiter was now known, remained a backup but it was the moment the two agencies had sought since 1954. Then, on the night of November 20 Vanguard was readied for take-off, was fired, exploded, and sat burning on its launch pad in the flat glare of international publicity. Orbiter's moment had arrived.

When von Braun blurted to McElroy that the hardware was on the shelf he was correct except for one detail: the satellite itself had yet to be built. Von Braun confidently assumed his team would get that plum, but Pickering was determined to shake it free for JPL. The laboratory had earned the job because of its work on Orbiter and the RTV, and the payload logically fit with JPL's communications work, particularly Microlock. Just prior to the meeting at which the roles would be assigned, Pickering asked Medaris for a few minutes alone. He argued that JPL should build the satellite; Medaris agreed. The general probably felt the laboratory could handle the electronics work better than Redstone, and he wanted to keep JPL actively in the Army's orbit. Von Braun's jaw dropped when Medaris and Pickering walked into the meeting and informed them of the decision, but the collaboration proved fruitful and there was more than enough work for both teams. The quarter of an hour Pickering spent with Medaris was momentous. If Redstone had built the Explorer I satellite, it would have had a lock on both the missile and the satellite. JPL would have been relegated to a minor supporting role, chiefly in its tracking network, from which it would have been highly unlikely to develop into a major space laboratory. Electronics, which had begun shouldering propulsion aside as the Jet Propulsion Laboratory's dominant activity during the Corporal weaponization, opened a window to space for JPL.[19]

Laboratory personnel worked intensively on what was code-named at JPL "Project Deal." Project manager Jack Froehlich, a formidable poker player, had bestowed the name in the aftermath of the Sputniks with the remark: "When a big pot is won, the winner sits around and cracks bad jokes and the loser cries, 'Deal!'" The next round was coming up even sooner than the ninety days Medaris had promised, for scheduling conflicts at the Cape dictated that the vehicle be ready for launching by January 29, 1958, just eighty days after the go-ahead. Although Vanguard had promised a twenty-five-pound payload, JPL more cautiously elected to limit theirs to twenty pounds. The payload structure weighed 30.8 pounds, including just 18 pounds for the instrument compartment. Three relatively simple experiments were chosen to investigate the satellite's environment, about which little was known. The first two, although having some scientific merit, were designed primarily to furnish information for future satellite design. The first experiment tested the extreme temperatures the satellite would encounter as it passed from full sunlight to the complete shade of the earth. A thermistor measured the internal temperature of the high-power transmitter

and the satellite's skin temperature. Resistance thermometers performed a second skin measurement as well as one of the nose cones. The second experiment measured the impact of micrometeorites on the satellite's surface by means of an impact microphone, an amplifier, and a circuit of eleven wire grids. The third experiment was primarily scientific and resulted in the most dramatic findings of the early satellite programs. This was the cosmic-ray experiment of James Van Allen of the State University of Iowa and involved placing a Geiger-Mueller counter and associated equipment in the satellite to measure radiation. Originally programmed for Vanguard, the Van Allen experiments were added to Explorer at Pickering's suggestion.[20]

JPL's work on Explorer was relatively straightforward, and surprisingly informal. Two considerations -- shape and temperature -- were among the main design constraints in designing the fourth stage. At first JPL engineers considered but rejected a spherical shape. A sphere probably could not be made rugged enough to survive launching through the atmosphere without either adding too much weight for strengthening or adding a protective cone. A cylindrical shape seemed preferable. This shape was consistent with the last stage rocket motor and with the instrumentation to be carried. The final stage measured eighty inches long and six inches in diameter. The easiest and most reliable way to counteract the extremes suggested extensive insulation and a careful ratio of bare steel, which provided a relatively high temperature, and aluminum exide, which furnished a low temperature.[21]

Two typical JPL approaches to design characterized the design and fabrication. First, simple, reliable components were used instead of more complicated designs which might have yielded higher performance but presented more design risks. The booster stages, for instance, used the relatively small six-inch scale Sergeant motors. These units had undergone more than 300 static tests, 50 flight tests, and 290 ignition-system firings without a failure. Second, the laboratory used to the maximum the experience its engineers had derived from the minute details of manufacturing. For instance, it was very difficult to determine malalignment of the components because the simple methods of measurement were less accurate than the malalignment itself. JPL engineers thus precalculated the malalignment of all components "with only experience as a guide"; this made possible field assembly of the large rotating second stage with a malalignment of less than 1/1000 of an inch. In another case a structural engineer checked the strength of a motor case by standing on it until it was deformed the maximum amount and observing that it suffered no apparent ill effects; these informal findings were later confirmed by sophisticated spin tests. Such techniques had contributed to JPL's problems in preparing drawings and insuring reproducibility when dealing with contractors in its missile programs, but for producing a limited edition prototype under severe time pressure experience proved a trustworthy guide.[22]

Third, dual or triple systems were used wherever possible so that a malfunction would not endanger a system or the entire mission. The igniter, for instance, might have to be fired in a vacuum; its failure would abort the mission. Three safeguards were employed: the igniter was designed to fire in a vacuum, the motor was sealed to hold atmospheric pressure, and the igniter was sealed in a container holding atmospheric pressure. The last two considerations added slightly to

the weight, but the added weight purchased much greater reliability at low cost. The concept of dual or triple systems, known as "redundancy," came to play a vital role in space missions.[23]

Besides work on the Explorer itself, JPL had to quickly expand the tracking network. Two primary Microlock stations already existed from previous experiments, Earthquake Valley near San Diego, California, and Air Force Missile Test Center in Florida. JPL designed equipment for new stations, which were set up in Nigeria and Singapore in cooperation with the British IGY committee. These stations were to snare telemetry data from the experiments. The orbital calculations would be handled through the Florida and California stations, and since Explorer I was launched eastward, an hour and forty-five minutes would elapse before confirmation of orbit would be possible.[24]

By early January JPL had finished its booster stages and satellite and moved them to Cape Canaveral under extraordinary secrecy. After the Vanguard failure the Army had clamped maximum security restrictions around Explorer, which was known even in highly classified cables between Redstone and JPL as "Missile 29." Medaris wanted to make the preparations for launch appear to be just another Redstone missile test. Any JPL personnel who could be obviously related to a satellite launch, particularly project director Jack Froehlich, moved under elaborate decoy plans. Secrecy during the erection of the missile and mating of the upper stages was particularly sensitive. The upper stages were to be covered with canvas for the hurried predawn movement to the launch pad. Then the launching structure was brought up and the bird cages surrounded the missile so that the top section was not visible away from the launching area. Missile 29 could then be "identified as a Redstone since the part in view will appear the same as a standard Redstone booster." Medaris warned: "I cannot overemphasize the importance of these decoy plans and the absolute necessity of covering this launching as a normal test of a Redstone missile, and I desire well understood that the individual who violates these instructions will be handled severely."[25]

The preparations moved smoothly and by January 29 Missile 29 sat ready for countdown. The secrecy had to end somewhere, of course, and by then a crowd of VIPs and newsmen had journeyed to the cape, but under an agreement by which no news was released until after the launch. Missile 29 perched on the pad for two days while flight personnel consulted weather forecasts as anxiously as General Eisenhower before D-Day. On the 29th and 30th high winds from the jet stream forced postponement; the engineers feared the missile could not stand the force. But on the 31st the winds, while still strong, subsided enough to justify the risk. The countdown proceeded normally and was only twenty-five minutes behind schedule. At JPL engineers clustered around the teletype hookup to the cape and watched anxiously as a nervous operator tapped out the events of the last minute of counting:[26]

X-1 AND COUNTING

2247EST

K

NO TIME WILL BE GIVEN FROM HERE ON IN

45 SECONDS

20

15

10

9S

7 6 54 3 2 1

BAST OFF

PROGRAM STARTED

LIFT OFF

Inside the blockhouse at the cape, Medaris listened intently to the principal indicator that the rocket was climbing steadily: a whining signal transmitted from the nose cone. Then it stopped. "I've lost my signal!" cried Medaris. A signal going dead usually meant missile failure. "Oh, oh . . . Too bad . . . This doesn't look good," murmured crewmen. An army captain ran to a phone, dialed the central recording station. "Signal lost at the blockhouse. How's yours?" The reply: "Noisy but legible." After forty anxious seconds of seeming failure, the crowd pressed into the blockhouse was reassured.

STILL GOING AT ONE MIN NOW

STILL GOOD

90 SECONDS

GOT THROUGHT THE JET STREAMS

EVERY THING NORMAL LOOKS GLO XX GOOD

110 SECOND NOW 115

R140 SECONDS

145

APPROACHING BURN OUT[27]

After 155 seconds the first-stage rocket burned out and fell into the Atlantic. As the vehicle coasted upward past 200 miles the guidance system tilted the assembly into a horizontal path. At 225 miles and 403.7 seconds, when the missile's position paralleled the surface of earth, a ground signal ignited the second and third stages. The velocity increased quickly, from 5520 miles per hour to 17,680 miles per hour. After 428.6 seconds of flight -- nine more than predicted -- Explorer I reached an altitude of 228 miles, ten miles higher than forecast. The fourth stage rocket ignited and gave the final stage a kick that should have sent the satellite into orbit. At the Pentagon, where another watch party was going on, von Braun turned to Pickering and said, "It's yours now." JPL took control. "Right, it's ours now," said Pickering.[28]

The Associated Press moved a story from the cape:

> THE ARMY'S JUPITER-C MISSILE BLASTED OFF FRIDAY NIGHT, CARRYING A SATELLITE INTO SPACE. ARMY OFFICIALS SAID IT WOULD NOT BE KNOWN FOR ABOUT TWO HOURS WHETHER THE MISSILE HAD SUCCEEDED IN PROPELLING THE FIRST AMERICAN 'MOON' INTO ORBIT AROUND THE EARTH.

JPL personnel in Pasadena felt helpless. There was nothing to do but wait and be poised to pick up Explorer's signal, if it was in orbit.

GEN MEDARIS SAID HAVE A CUP OF COFFEE - SMOKE A CIGARETT SWEAT IT OUT WITH US

K

OK TNX LXX ALOT DAY WILL DO

K

DE JPL

WE ARE BEING NONCHALANT AND LIGHTING UP A MARJAUNA

HA[29]

The laboratory crews were anything but relaxed. At the cape Medaris and other officials kept popping into the JPL data analysis room for assurances Explorer was in orbit. Froehlich, Stewart, Al Hibbs, and other laboratory personnel were poring over the telemetry from the down-range stations, in order to send their West Coast colleagues a prediction of when the bird should pass. The velocity seemed adequate for orbit, they knew, but they had no data on the angle of inclination. "The thing could be pointing up too high or pointing down so low from the horizontal that it would have been a disastrous launching," Stewart recalled. As best they could figure, Explorer should pass within about 105 minutes, or certainly by 110 minutes. But Explorer did not show. Seven minutes late; everyone throughout the organization was "really getting pretty upset." Eight minutes late. Finally the San Gabriel Valley Radio Amateur Club near Pasadena, followed quickly by the Earthquake Valley Microlock station, picked up the signal. The satellite was late because the jet stream had given it an extra kick of about 100 feet per second, which sent it into an orbit with a higher peak, and hence longer transit time, than JPL trackers had thought possible. When injected into orbit the object enjoyed ample margin for error; its position was only about 0.8 degrees from the horizontal, but a satisfactory orbit would have been possible with a deviation as great as 4 degrees. Explorer I's apogee was 1580 miles, its perigree 223 miles, and the time for one orbit 113.2 minutes. Explorer I was in orbit, and JPL was jubilant.[30]

When the Microlock snatched the signal from space, it also turned the international limelight on JPL. No longer an obscure Army laboratory known chiefly to missile cognoscenti, JPL basked happily in the warm glow of favorable publicity. Pickering, Van Allen, and von Braun hoisted a model of the Explorer I satellite over their heads at a Washington news conference the next day, and a wire-service photograph of the occasion appeared in hundreds of American newspapers. The New York _Times_ ran a sidebar on the laboratory, and _Time_ included a profile of Pickering with those of Medaris and von Braun. Most of the attention focused on von Braun and his colleagues; preoccupation with the more dramatic and more easily understood rocket booster, and with the human-interest story of the former Germans working for America, was perhaps understandable. No matter. JPL was bursting with pride, and already dreaming of a major role in space exploration. In triumph, and in defeat, JPL would not return to its former obscurity.[31]

* * * * *

JPL and ABMA continued to collaborate on a series of Explorers through July 1958. They were designed to exact quickly the maximum mileage from existing technology, and they focused on the intriguing cosmic ray data returned from Explorer I. While basically similar to the first satellite, they introduced some refinements in the payload. Explorer II, launched on March 5, 1958, did not achieve orbit when,

because of a structural failure, the fourth stage failed to ignite. Explorer III placed the second successful American satellite into orbit on March 26, 1958. Meteorite and temperature measurements resembled those on Explorer I. The major innovation was a tape recorder that made it possible to transmit much fuller cosmic-ray data. Because of the small number of tracking stations, much of the orbit could not be observed; just as this had caused an anxious two hours on January 31, it also meant that much of the telemetered data was lost. Explorer III contained a miniature tape recorder. Moving at a very slow rate of .005 inches per second, the recorder needed less than three feet of tape to freeze the data from an entire orbit. When the satellite neared a tracking station, a ground signal switched on the playback head and the high-power transmitter. In less than five seconds all the data from the orbit was sent, and the tape was erased and reset.[32]

The returns from Explorer III continued to astound scientists. Pulse rates at the apogee of the orbit registered at least a thousand times what had been expected; counts exceeded 35,000 per second at the highest altitudes, over South America, and saturated the Geiger-Mueller counter. The data from Explorers I and III enabled Van Allen to announce on May 1, 1958, the discovery of "a very great intensity of radiation about altitudes of some 500 miles over 34 degrees north and south of the equator." He theorized that these phenomena, ultimately known as the Van Allen belts, consisted of charged particles trapped in the earth's magnetic field.[33]

These extraordinary findings led JPL, ABMA, and IGY scientists to devote Explorer IV entirely to radiation studies, in conjunction with the novel Argus experiment. The satellite was launched successfully on

July 26, 1958, and carried almost twice the weight of instrumentation of the previous vehicles. Van Allen developed new instruments that could record 60,000 particles per square centimeter per second, several thousand times that previously measured. Explorer IV recorded data from areas not sampled previously. Its predecessors had ranged between 35 degrees north and south latitude; Explorer IV covered most of the Earth's surface, with extremities at 51 degrees. The Argus experiment provided data never present before. In late August and September the Navy sent three rockets to an altitude of 300 miles over the South Atlantic, where small atomic bombs were exploded in brilliant pyrotechnic displays. Explorer IV's instruments recorded the radiation from the explosions that was trapped in the atmosphere and made possible considerable refinement of the knowledge of the Van Allen belts and related phenomena. Explorer V failed to achieve orbit. The radiation experiments of the three successful Explorers had scored a scientific coup with what Van Allen aptly termed "the most interesting and least expected results" of the probes.[34]

The last major phase of the program to adapt existing technology to quick and easy projects bore fruit in Pioneers III and IV. These ventures were essentially simplified revisions of the ill fated Red Socks proposal. ABMA substituted a modified Jupiter-C missile, which developed 150,000 pounds of thrust, for the 78,000-pound-thrust Redstone. JPL's three spinning upper propulsion stages remained basically the same. The payload contained the familiar temperature sensors and Geiger-Mueller counters; the laboratory added a shutter-trigger mechanism that was supposed to be tripped by the reflected

light of the moon. The 12.95 pounds of instruments were housed under a striped conical hat that somewhat resembled the canopy of a merry-go-round.[35]

Two Pioneers, designed by the Air Force and Space Technology Laboratories, preceded the JPL-ABMA combination in the fall of 1958. Neither worked, and the laboratory and the Army again had a chance to upstage a rival service. Pioneer III was launched from Cape Canaveral on December 6, 1958, but it did not achieve escape velocity when the first stage cut off prematurely. The payload rose to a height of 63,500 miles, about 7,000 miles short of the previous Pioneer. Nevertheless, two of the flight objectives were partially met; the new Goldstone station tracked the probe without a hitch, and the radiation counters returned further refinements of data on the Van Allen belts.

Before JPL-ABMA had a chance to try again, the Soviet Union sent Luna I toward the moon on January 2, 1959. Later renamed Mechta, or "Dream," Luna I passed within 3,728 miles of the moon's surface and passed on into orbit around the sun -- the first vehicle to escape Earth's gravitational attraction. The flight of Pioneer IV, launched on March 3, 1959, therefore seemed anticlimactic, although it was by far the most successful of the Pioneer series. The probe passed within 37,200 miles of the moon 41-1/2 hours after injection. The light mechanism stayed dark because it had been programmed to operate when Pioneer came within 20,000 miles of the moon. The tracking system worked superbly, however, and received Pioneer's signals until the spacecraft's batteries failed about 407,000 miles from Earth. Pioneer IV followed Luna I into orbit around the sun, becoming a planet that completed a circuit every 395 days.[37]

Pioneer IV augmented JPL's sense of accomplishment and feeling of superiority; the laboratory and the Army had again bested its American rivals. Hastily modified existing technology had put the United States on the board in the space derby. But the Soviet successes continued to rankle and encouraged JPL officials to press for a more vigorous space program. Modifications of existing technology had reached their limits. JPL engineers had recognized early in 1958 that the Juno I and II series represented a string of improvisations -- useful for the moment, perhaps, but not at all what they believed a credible United States space program demanded. The laboratory's ambition for international leadership in the space program had already been translated into a dynamic, abrasive presence in a new civilian space agency and an ambitious space program.

NOTES

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ORGANIZING FOR SPACE, 1958-1960

The Jet Propulsion Laboratory brought to the space program a heritage of reaching for big problems. In both propulsion and communications JPL had aimed at the major problems in the field instead of merely refinements in existing knowledge. From the earliest days of space interest the laboratory felt the lure of deep space, particularly planetary exploration. John Small, a senior engineer at the laboratory, once explained the JPL ethos as wanting "to do the final far-out things." JPL would rather go to Saturn's rings than understand the Martian surface, make the life measurement on a planet than land a capsule, and land a capsule than build the spacecraft. JPL's earliest space planning called for flights to Mars as early as the fall of 1960. But reaching for the "final far-out things" also involved a determination of the role the laboratory would play in more mundane matters, such as the propulsion vehicle. And the path to deep space required sure footing in the political mazes on Earth.[1]

The laboratory at first continued its familiar alliance with the Army Ballistic Missile Agency. The two organizations' research and development areas complemented each other, and Wernher von Braun's overpowering interest in building a giant booster rocket dovetailed with JPL's deep space interest. ABMA's ambitions were nothing short of breathtaking; a plan it put together early in 1958 contended a four-man experimental space station was feasible by 1962, a manned lunar expedition by mid-1966, a permanent moon base by 1973, and the first manned expedition to a planet by 1977. The first step was the need for a more advanced vehicle than the Juno II, which powered the Pioneer flights. Juno III, which they proposed in March 1958, would consist of a Jupiter and high-speed upper stages similar to Juno II but of greater capacity. Medaris proposed that by spring of 1959 a Juno III with a 120-pound payload could swing past the moon at a distance of 5,000 to 10,000 miles and photograph the back side, heretofore never seen by man; by late 1959 a Juno III could manage a hard landing with an instrumented payload on the lunar surface. (Medaris' timetable was hopelessly optimistic. The first United States spacecraft to achieve a hard landing on the moon would be Ranger in 1964, and the Soviet Union would easily beat America cameras to the back side.) Juno III had no sooner been proposed than JPL expressed second thoughts. Juno III fell between two stools: It was too big for minimum probes, which Juno II could handle, but not big enough for more advanced missions that would be guided and fully instrumented; the simplicity of the spinning cluster was lost when the rotation had to be stopped to apply accurate final stage speed or direction controls. Juno III was thus a "closed-end development" that was "not really compatible with the expected course of developments in the guidance field."[2]

Juno III had been devised to meet a Department of Defense request for readily available technology for military satellites. JPL soon concluded, however, that it wanted to push beyond existing technology and deeper into space. It was time, the laboratory argued in April 1958, to embark on a "really integrated propulsion system with growth potential and broad usefulness in other programs." The basis of this departure, billed as Juno IV, would be the familiar Jupiter. In place of the three unguided, solid-propellant upper stages of Junos I-III, however, Juno IV would use two more powerful and more sophisticated guided, liquid-propelled upper stages. JPL argued that it should have responsibility for both the 45,000-pound-thrust second stage and the 6,000-pound third stage. The laboratory insisted, moreover, that it exercise responsibility for space missions. ABMA would continue development of Jupiter and exercise responsibility for satellites and lunar probes. The Army at first demurred but then accepted JPL's ambitions.[3]

But the fate of the Juno IV proposal at the hands of higher authority in August 1958 alarmed JPL. The Eisenhower administration had established the Advanced Research Projects Agency in the Department of Defense in February 1958 to handle the military space program and to act as a caretaker for any eventual civilian space projects. ARPA's main interest in 1958 lay in reconnaissance satellites; lunar projects were secondary; and deep space was too remote for ARPA to contemplate just then. ARPA approved JPL's proposals for an improved tracking system, based on the new Goldstone station, which could grow eventually into a deep space tracking facility. But the agency sank JPL's propulsion hopes. ARPA substituted the 45,000-pound engine General Electric was developing for Vanguard for JPL's second stage. The laboratory was left with just its 6,000-pound upper stage and whatever it might be able to salvage from satellite and lunar missions.[4]

JPL's military alliance was changing, for by the summer of 1958 a consensus was forming nationally that a civilian agency should play a major role in space exploration. The military would retain a satellite role and perhaps something more, but the Air Force, not the Army would run the military space program. JPL officials were divided on the advisability of hitching their destiny to the civilian star. Many persons at JPL found the military grooves, classified documents and closed doors comfortable. Some JPL technical staff members had worked happily in early space intelligence activities, such as Project DUB. Some favored setting up a space program within the Atomic Energy Commission, which boasted a reputation for skilled scientific work under tight deadlines and also had a long-range interest in applying nuclear propulsion to rocketry. But by spring 1958 JPL found the idea of a civilian agency increasingly attractive. As one of Director William H. Pickering's aides, J. D. McGarrity, put it: JPL and Caltech had "almost . . . a moral obligation to see that the assets in a unique organization like JPL . are not restricted to serve only the military." President Dwight D. Eisenhower proposed the civilian agency in April 1958. On July 29, 1958, he signed the bill, which an eager Congress had broadened and strengthened, that created the National Aeronautics and Space Administration. If JPL wanted to see its idea of a space program develop, the laboratory needed to find an institutional home in NASA.[5]

The danger, as many JPLers saw it, was that NASA had been created from the old National Advisory Committee on Aeronautics. NACA, a federal research establishment dating to 1915, had done much important early work in aeronautics; Pickering credited NACA with developing the modern airplane. But JPL staffers, who tended to be disdainful of civil service science in general, thought NACA by the 1950s had become an unimaginative bureaucracy more concerned with pushing known principles to the next decimal point than in making genuinely original discoveries. Perhaps even worse for some JPL staff members, NACA seemed to have become little more than a service bureau for the Air Force and aircraft firms. The new NASA would be "filled rapidly by jelly-fish type individuals," predicted Cliff Cummings, a senior JPL engineer. NACA's ideas of program and organization seemed, furthermore, to threaten JPL. NACA planning focused on satellites. For instance, the Stever Committee, chaired by H. Guyford Stever of MIT, did not include lunar or planetary flights in its report in the fall of 1958. The organizational strategy suggested that NACA would slowly grow into NASA. The new agency would conduct research at its own civil service centers and contract outside extensively, chiefly with aircraft firms.[6]

The NACA concept of a space agency seemed both to threaten JPL and present it with an opportunity. The danger was that the laboratory's role could be marginal or, indeed, that an undynamic NASA might falter. The lure was that JPL could perhaps fill the vacuum and push through its ambitious program plans. JPL was "uniquely capable of playing the primary role in the Nation's space program," Pickering said. No other laboratory could boast its wide experience in the key fields of rocketry or its percentage of talented professionals, JPLers believed. Explorer, and later Pioneer, seemed

confirmation enough. If NACA exhibited a governmental bias, JPL hands attributed much of their success to standing outside civil service. The Jet Propulsion Laboratory viewed itself as indispensable to a dynamic space program. When James R. Killian, Eisenhower's science advisor, pondered JPL's role in NASA, Pickering argued:

> I believe that it is essential for the new agency to accept the concept of JPL as the national laboratory. If this is not done, then NASA will flounder around for so long that there is a good possibility the entire program will be carried by the military with NASA providing only some research support and perhaps helping with scientific payloads. If JPL does become the national space laboratory on the other hand, then not only does a complete experienced laboratory knowledgeable in all phases of the problem become the key asset of NASA, but there is assurance that a realistic program will in fact be established and pursued. As you well know, one of the problems in the present space program is the multiplicity of committees and groups which are planning programs. It is essential for some competent group to be given a clear cut responsibility and told to draw up a realistic long term program which they can successfully complete on schedule.

Perhaps renamed "National Space Laboratories," as some JPL engineers suggested, the Pasadena laboratory would dominate NASA.[7]

Pickering and Caltech President Lee A. DuBridge responded eagerly to the first NASA overtures in the fall of 1958. When NASA began operation on October 1, 1958, there was a growing sense within the organization that a more ambitious program than what NACA had outlined should be attempted. This view reflected in part the ideas of members of the Naval Research Laboratory, which NASA absorbed on October 1. Although JPL had tended to diminish the Navy laboratory's capabilities because of its civil service connection and its misfortunes with Vanguard, NRL personnel displayed competence and imagination that would surprise and sometimes confound JPL. The first NASA administrator, T. Keith Glennan, president of the Case Institute of Technology in Cleveland and a former AEC commissioner, also favored a more aggressive program. Glennan wanted to snatch the Army's entire space package -- ABMA and JPL -- so that NASA could "acquire at the earliest possible date a developmental and operational capability for large space vehicles." The NASA chief did not want to depend on the military services for vehicles. ABMA boasted experience in complete space vehicles. "JPL has strong capabilities relating to small payload packages, guidance, electronics and to upper-stage booster systems, and high-energy rockets, thereby complementing ABMA's limited experience in these fields," a NASA staff report noted. To develop facilities equivalent to JPL would require $60 million, involve recruiting 2,000 to 3,000 people, and take three or four years.[8]

The Department of Defense did not want to lose JPL. Assistant Secretary of Defense Donald Quarles argued that the laboratory, particularly its work on the Sergeant missile, was too important to national security to allow the changeover. But the Army wanted desperately to keep ABMA to maintain its toehold in long-range

missilery. A compromise was reached quickly. NASA would get JPL; the Army would keep ABMA for at least another year. In three short negotiating sessions, NASA and DOD worked out the arrangements for transferring JPL property and personnel. The laboratory would see the Sergeant program to completion which was expected in 1960, and it would continue to do some research for the Army. Eisenhower signed an executive order approving the transfer on December 3, 1958, and the bulk of JPL efforts came under NASA jurisdiction on January 1, 1959. The space agency contract paralleled the one JPL had enjoyed with Army Ordnance, thus allowing the laboratory to retain wide discretion in its operations. The second NASA administrator, James E. Webb, said he would never have written the contract that way, but any doubts that surfaced in 1958 were submerged by the sense of urgency and desire for a smooth transition.[9]

As JPL and NASA embarked on their uncharted course, neither organization had assimilated the other's ideas about their respective roles. DuBridge told the Caltech trustees that "JPL will be NASA's major space flight laboratory." But NASA officials, while not yet definite, seemed to have more modest ambitions for their acquisition. A draft outline of JPL's mission in October 1958 by NASA headquarters pointed first to: "Supporting research in communications, telemetry, guidance and control, rocket propulsion utilizing both solid and liquid propellants and in related fields -- all subject to coordination with other Centers to avoid undesirable duplication." Secondarily it sketched: "specific interplanetary mission assignments together with related research and development including, in some cases, technical direction." The vast gap between these two concepts of roles would fuel controversies for years.[10]

* * * * *

One of the first products of JPL's relationship with NASA was a long-range program for space exploration. As Pickering had told Killian, planning for space exploration had heretofore been haphazard, even schizophrenic. Program sketches had veered from NACA's penchant for cautious incremental advances to ABMA's excessively exuberant plans for manned vehicles to range throughout the solar system in the next decade. Both extremes had in common the assumption that almost anything, whether small or large, could be justified in the space program. NASA agreed to fund a $1.3 million study at JPL in October 1958, even before negotiations to add the laboratory to the new agency had been completed. JPL officials felt they were outlining not only the laboratory's future program but NASA's major space program. From November 1958 through January 1959 several top staff members of the laboratory devoted considerable time to what would prove to be a revealing study.[11]

The first flight, a circumlunar probe, would take place in July 1960. Two Mars flights would follow in October, when the red planet made its nearest approach to Earth. A brace of flights to Venus would occur in January 1961. During the next eighteen months, when Venus and Mars were too far away for favorable launching conditions, JPL would practice with an escape out of ecliptic orbit in September 1961 and a lunar satellite in April 1962. Venus satellites would follow in summer 1962 and Mars near misses late in the year. With the planets again out of position in 1963, three lunar flights were scheduled. The planners listed flights after 1963 as tentative. They consisted of Venus landings in the spring of 1964, a manned circumlunar

flight in August 1964, and a manned flight around Mars and return in January 1965. The JPL timetable of eighteen flights in five years was exceedingly optimistic. The Mars probes scheduled for 1960 represented a big jump over the Pioneers the laboratory was engineering at the time of the planning study, and some of the flights outlined have yet to be attempted. But some JPL participants felt the sketch might be criticized as too conservative, and they pondered "spicing it up with 'spectaculars.'"[12]

Since the plan was the first systematic look at space exploration by a NASA agency, it revealed much about early thinking about space even though it was not implemented. Other studies had tended to look first at technology and try to find a mission to fit; JPL decided instead that missions should come first and then vehicles, tracking, facilities, and the like could be made to fit. The plan revealed, first, JPL's commitment to planetary exploration. The lunar flights, while of some intrinsic merit, played a role primarily as test runs for the planetary voyages. Second, the leading criterion that guided the choice of missions was technical feasibility. The timetable took advantage of every opportunity when Mars and Venus assumed the best positions for launches. Feasibility was linked, thirdly, to dramatic impact. "The public demands sudden and spectacular achievements from their [sic] space program," the final report concluded. JPL ranked "public reaction" second only to feasibility in the scale of criteria for mission choices; scientific and technical merit ranked third. Indeed, scientific objectives were sketched only in general terms and they were made to fit around the missions; the choice of missions was not based on a survey of the key scientific questions to which the space program might address itself. Pickering told Medaris that through mid-1962 "scientific experimentation would be carried along when space and time permitted." The laboratory, fourth, did not at this point anticipate the gap that eventually arose between proponents of manned and unmanned space flight, with scientific advocates usually favoring the unmanned segment. "Certainly, a manned landing on another planet is one of the most important objectives of a long-range program," the report said. "Regardless of how clever we become with remote measuring devices, one hard-rock geologist landed on the moon, for example, would be worth many tons of automatic equipment."[13]

In the course of the study the JPL planners sometimes worried how space exploration might be justified and considered drawing on the Caltech humanities division for help. In the report, however, possibility became its own justification. The laboratory, like NASA throughout much of its early history, did not so much answer the question of justification as assume that a putative public demand for firsts in the space race provided one. To JPL early unmanned deep space probes offered the best route for fast, dramatic bursts in the space race.

Once JPL had selected the missions, it began to fit the hardware around them. The main technical problem in NASA's first several years was building reliable first-stage boosters. James D. Burke, who headed the propulsion segment of the study, outlined a plan for a "unified vehicle family." He hoped to see NASA select a minimum of basic designs and stick with them so that they would develop the maximum experience and reliability. IRBMs were considered but discarded in favor of the larger ICBMs. The laboratory proposed three classes of vehicles. Providing an escape payload of 150 to 300 pounds, Vehicle A would consist of an ICBM and appropriate upper stages; Vehicle B would be similar but larger and provide 300 to 1000 pounds payload. The third class, Jupiter V, eventually known as Saturn I,

was tagged as the deep space workhorse vehicle. Von Braun's dream child, Jupiter V consisted of eight to eleven Jupiters strapped together to develop 1 to 1.5 million pounds of thrust. ABMA thought it would be ready in 1962. In JPL's outline the first stage boosters of the early years would become the second stage vehicles of the Jupiter V. The laboratory tried to preserve its rôle in propulsion by emphasizing the importance of the 6K rocket it already had under development for the final stage. NASA accepted the vehicle plan largely intact, for it seemed to offer a rapid, reliable way out of the forest of conflicting rocket designs. JPL also outlined major expansions of tracking and other facilities that its program required. These remained to be hammered out with NASA as actual program and budgetary decisions materialized.[14]

NASA officials reviewed the program at the Pasadena laboratory on January 12-13, 1959. The first full-dress session between JPL and NASA officials, the meeting revealed some agreement and yet some significant gaps in understanding between JPL and NASA. Pickering said the laboratory wanted to continue a balanced overall program of supporting research, advanced development, and development. "A strong 'in house' capability is necessary to maintain technical competence," he said. "The Laboratory expects to give support to NASA," the JPL minutes continued, "but it is hoped that technical supervision of programs other than those in which the Laboratory has a direct interest will be kept to a minimum." Pickering stressed the necessity of a long-range view and hoped that all of JPL's work in 1959 would be directed toward deep space.[15]

Dr. Abe Silverstein, director of NASA's Office of Space Flight Development, agreed with the need for a long-range program. But he also stressed the need for producing immediately. Notes on Silverstein's remarks taken by Homer Newell, head of NASA's space science office, explained: "Longer range developm. -- of course. But must build up confidence of Congress so that they will provide the support." Silverstein wanted JPL to feel it was a part of NASA and was acting from the inside, not just as another contractor. "NASA has a rugged job monitoring nat'l program," Newell recorded. Silverstein put particular emphasis on the need for a national program, and his hope that JPL could help out broadly. The differences between Pickering and Silverstein represented more than nuances. The friction between short-term and long-term, and between national and parochial programs arose from the basic clash over the relative independence of JPL within NASA.[16]

JPL pressed NASA hard early in 1959 for authorization to take the first step in its space program, Project Vega. Three early rounds were programmed in accordance with the JPL five-year plan -- lunar and Mars probes in the second half of 1960 and a Venus flight in 1961. (The fourth would be a new meteorological earth satellite; two to four more flights would be determined later.) The vehicle for these flights consisted of a payload and a three-stage rocket. The first stage Atlas would be developed by Convair Astronautics, the second would employ the Vanguard rocket designed by General Electric, and the third would use the 6K segment JPL had been working on. Vega was only an interim vehicle, whose usefulness would extend only until the Centaur was ready in 1962; but Pickering told Glennan in 1959 it ranked nonetheless as "one of the most important actions which NASA must take this year." Vega promised a quick planetary capability, and some of the program's segments would become building blocks for later developments. As the first vehicle system NASA would build under its own direction and for scientific and civilian purposes, Vega would free the agency from its

dependence on military vehicles. If NASA did not inaugurate Vega at once, Pickering pointed out on March 24, 1959, two serious consequences would follow. First, the Mars 1960 flight would have to be scrapped, "with consequent loss of prestige to both the U.S. and NASA." Second, any slippage in development would endanger Vega's lead time over Centaur and give force to the argument that NASA should just wait for Centaur. The desire both to start a planetary flight program quickly and to free NASA from its military dependency induced JPL to cast its lot with Vega.[17]

After long delays in its chaotic early months, NASA finally authorized the Vega program at JPL on March 26, 1959. From the start a host of problems -- budgetary, organizational, and technical -- plagued Vega. The project never received the financial support it needed but had to operate under serious budgetary and manpower restrictions, especially in the areas outside propulsion. By 1959 NASA had assigned priority to Project Mercury, the United States' first man-in-space venture, which left Vega constantly underfunded. JPL faced continual organizational woes. The laboratory had the role of project manager to supervise and integrate the whole effort, but it did not have the authority to match. Unlike the Sergeant missile project, where JPL had enjoyed technical control and considerable contract authority, the Vega operation left open virtually two lines of authority to the contractors -- one from the laboratory, the other from NASA headquarters. JPL felt the contractors sided with the agency holding the purse, NASA headquarters. The agency's Washington office seemed continually confusing to the laboratory. Instead of one central project office, as had been set up for Mercury, Vega efforts required time-consuming and sometimes contradictory coordination with each of the major branches in NASA. Finally, the schedule for launchings slipped badly. There simply were not enough launch stands available in the country to wedge in Vega firings, and NASA was slow in contracting to build additional stands. By November 1959 the first launching, originally slated for summer 1960, had slipped to March 1961. Vega's margin over Centaur had diminished to a critical point.[18]

The technical difficulties and high costs of space technology, moreover, added to doubts about the possibility of meeting Vega's ambitious schedule. Consider guidance, one of JPL's prime responsibilities. No American space probe launched through the summer of 1959 could boast of guidance into or after the injection phase. The most advanced spin-stabilized vehicle was estimated to have no better than an even chance of impacting the moon, and some estimates ranged as low as ten per cent. True space-mission capabilities required guidance not only through injection, however, but also the capability both to perform midcourse corrections and to complete terminal maneuvers, whether for orbit or soft landing. JPL engineers began to think that the sensible course would be to use lunar flights as the proving ground for developing all the elements of a spacecraft system. The shorter distance to the moon made possible more economical development, and the more frequent launch opportunities promised faster progress. Without question the lunar emphasis weakened the planetary program that JPL desired. But as a laboratory report pointed out in October 1959: "It is impossible, in a six-vehicle program having the current manpower and funding limitation, to mix equally lunar and interplanetary programs without seriously jeopardizing the whole program." It was also impossible, the report concluded, "to adequately disguise an interplanetary program as a lunar program." The laboratory thus argued for "a strong lunar program in which the interplanetary capability

is less than optimum."[19]

JPL was in part making a virtue of necessity, for by the fall of 1959 Vega little resembled the scenario of a few months earlier. Aiming at the most difficult problems first, JPL engineers had pitched their initial designs at the Mars 1960 probe. They soon decided that a Mars mission posed too many technical barriers for so new a program. The Mars mission, which Hibbs had once termed "of the utmost importance," faded out in June 1959. A more realistic Mars attempt was sketched for October 1962. Glennan got cold feet about the Venus mission also in the summer of 1959. He pointed out to Eisenhower that the proposed launch, in January 1961, would be only the first or second firing of the Vega vehicle, "and the chances of full success seem[ed] quite low." The NASA administrator deferred the Venus venture until 1962, when it would again assume an approachable position. By the fall of 1959 the first four Vegas had been cut back to lunar missions, the first of which would take place in March 1961. The planetary probes would have to wait until 1962. If the schedule slipped much more, Vega would become an example of the very problem it was supposed to correct: a short-term vehicle that would be used for too few missions to assure much reliability and then would be discarded.[20]

Despite these problems Vega might have survived had not a competitor surprisingly emerged from the murky waters of the military-space bureaucracy. The rival was Agena-B, a clandestine Air Force project which had capabilities similar to the second and third stages of Vega. NASA and military officials had traded information on their vehicle plans in December 1958, and had formalized them in "A National Space Vehicle Program" on January 27, 1959. Agena had not been mentioned, even though the Air Force apparently began its development about that time. The Air Force used the Agena as the injection stage in its Discoverer satellite program -- a role Vega could easily have assumed. NASA did not learn of the interloper until late summer 1959. The duplication could not be justified; President Eisenhower reacted angrily when he heard of the Air Force's maneuver. But NASA bowed to force majeur; Glennan recognized the political clout the Air Force wielded in Congress. Even though Vega had prior rights to development, and its abandonment lost $17 million, he decided to cancel it and adopt Agena-B in early December 1959.[21]

"Quite a bombshell you threw at us," Pickering told NASA Assistant Administrator Richard Horner on December 8. The JPL head had learned of the cancellation only the day before; laboratory documents as recent as December 3 had still assigned Vega prominent roles. Glennan had informed Pickering of the decision but had not sought JPL's consent. The cancellation caused consternation at the laboratory. JPL had pinned most of its early space dreams to Vega; Pickering had expected that half of the laboratory's effort in 1960 -- almost everything except for the Sergeant missile -- would be devoted to Vega. The 6K propulsion development project was reduced to research status. This marked a historic turn in the laboratory. Never again would propulsion, the field in which the laboratory had first gained fame, assume prominence at JPL.[22]

"I look at this and get concerned over the whole plan of the Lab's part in NASA," Pickering told Horner. "The implication is pretty heavy as to reorientation of JPL." Horner agreed that the decision "must be disturbing in many respects to you and your staff." It would entail "a major reorientation" of the laboratory's work, he acknowledged. But the

cancellation, he continued, contributed to sorting out the roles of the NASA centers that Glennan had desired for some time. The space agency had finally wrenched ABMA from the Army. Von Braun's group would assume responsibility for launch vehicle systems. The new Goddard Space Flight Center in Beltsville, Maryland, would supervise earth satellite spacecraft and sounding rocket payloads. The Jet Propulsion Laboratory would take over the development and operation of spacecraft for lunar and planetary exploration. Although it meant abandonment of vehicle systems work, this was an ample assignment. Pickering acknowledged later the laboratory probably could not have maintained its propulsion and vehicle work along with the spacecraft assignment. In the short run, however, JPL officials had to determine where their space role would lead over the next few years.[23]

By the end of December JPL and NASA officials hammered out a revised space program for the laboratory. The solution blended headquarters' preference for lunar flights with JPL's designs for planetary exploration. Seven flights were planned. Five lunar reconnaissance missions were scheduled from spring 1961 through fall 1962; known as Rangers, these would use the Atlas-Agena B. Venus and Mars probes would follow in the second half of 1962; carrying the name Mariners, they would be propelled by the Atlas and the new Centaur. Both NASA and JPL agreed that it was "technically possible and highly desirable to fly early." This posed a high-risk decision. Since the Vega spacecraft had been targeted for planetary missions, it was more complex and potentially raised more problems than necessary in a lunar reconnaissance object. On the other hand, by making use of the design to that point, a continuation of the Vega plans had the appeal of potentially faster and more economical development. The Vega spacecraft thus became the basis for both Ranger and the early Mariners.[24]

In the aftermath of the cancellation of Vega, JPL's program for the last several years had been basically determined. The lunar program expanded rapidly in 1960. That summer the laboratory let contracts to four industrial firms to study the next phase of its lunar program, the soft-lander eventually known as Surveyor. As the Sergeant missile work was phased out, the Mariner projects, a formidable competitor to the lunar side, began moving up from the inside. By the end of 1960 Ranger spacecraft was nearing the assembly stage, and Mariner design concepts were approaching the first attempts at hardware.*

* * * * *

During the program reorientation of late 1959 and early 1960, the laboratory organization, which had been fairly informal, began to become more bureaucratized. Pickering appointed Brian Sparks as the first deputy director in 1959 and gave him considerable authority over day-to-day affairs. Two other staff engineers, J. W. McGarrity and J. I. Shafer, provided limited staff assistance to the director. Planning support came from a four-man planning staff headed by Assistant Director J. D. McKenney. Assistant Director Frank E. Goddard, who had been detailed to NASA headquarters for a time after the agency was formed, handled JPL-NASA relations. Business administration continued to be headed by Val C. Larsen, Jr., the third assistant director. Two

* Descriptions of the spacecrafts will be found in following chapters.

program directors rounded out the director's office: Cliff I. Cummings, who headed the Ranger effort, and Robert J. Parks, who ran the Sergeant missile program until the JPL portion was phased out on June 30, 1960, when he became full-time head of the Mariner program. Pickering also made increasing and more formal use of the senior staff, a group of twenty to thirty executives including the director's office staff, the division chiefs, and some administrative and selected other personnel. The weekly senior staff meetings were a significant forum for discussing laboratory policies.[25]

The technical work of the laboratory was organized in accordance with the "matrix" concept. The matrix would remain the laboratory's basic organization pattern for the next two decades, although it was subject to criticism and severe strains. Based on a study by the management analysis firm of McKinsey & Co., the JPL matrix resembled forms in use at Argonne Laboratory, Marshall Space Flight Center, Hughes Aircraft Corp., and other industrial firms. The line organization of the technical staff was divided among seven* technical divisions, somewhat analogous to university departments; then a small project organization would form a thin overlay across the divisions. The rationale behind the matrix concept was that the technical divisions carried the ongoing work of the laboratory while project offices were finite and subject to dissolution. Since several similar projects would be going on simultaneously, the best technical talent would presumably be applied to any or all of the projects as needed; scientists and engineers would not be pigeonholed on one project when their talents might be needed elsewhere. The division chiefs wielded great authority. They exerted considerable influence on the programs the laboratory undertook through their relationships with the director's staff and program offices. Within their satrapies the division chiefs planned and directed all the laboratory's activities; approved all personnel actions, except for hiring and firing section chiefs, which required the approval of the deputy director; shifted funds within programs; and controlled the facilities and equipment the divisions used on a long-term basis.[26]

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* The divisions and the sections under them were:

1. Systems: Program Support, Systems Analysis, Systems Design, Systems Test and Operation.
2. Space Sciences: Research Analysis, Space Instruments.
3. Telecommunications: Communications Systems Research, Communications Engineering and Operations, Communications Elements Research, Telemetering and Command Systems.
4. Guidance and Control: Electronic Devices, Sergeant Guidance Engineering, Guidance and Control Engineering, Electro-Mechanical Devices.
5. Engineering Mechanics: Materials Research, Missile Engineering, Professional Services, Engineering Research, Spacecraft Engineering, Design.
6. Physical Sciences: Chemical Physics, Gas Dynamics, Physics.
7. Propulsion: Solid Propellant Rockets, Solid Propellant Chemistry, Liquid Propulsion Research, Liquid Propulsion Development.

The program director had responsibility for the end product of a given program, such as the lunar program, after the general design approach had been settled by the senior staff. To accomplish this he had to rely on the technical divisions, and much of his time involved coordination with the division chiefs to insure they provided the work required. The program director tried to iron out jurisdictional disputes between divisions, although they could appeal to the deputy director. The program director also established liaison with contractors. His authority extended to programs, not personnel. His personnel authority reached only his immediate staff, which he was expected to limit "rigorously." For instance, Cummings had only his deputy, J. D. Burke, and two other engineers on his staff in mid-1960; but he drew on 600 professionals divided among the divisions. The interface between the program directors and the division chiefs posed potentially the most serious problem in organization. The matrix concept had considerable validity, especially as a means of insuring continuity of research and advanced development efforts, cross-fertilization of ideas, and recharging the staff through the rapid integration of new talent. As the laboratory became more heavily committed to programs with specific objectives and tight schedules, however, serious doubts emerged as to whether the program organization was strong enough.[27]

While JPL's internal reorganization took place, the laboratory also faced a difficult shakedown cruise in its external relations with NASA. McKinsey & Co. had warned that the "operation of a large laboratory, under contract with a private institution, presents problems unprecedented" by NACA's experience with its research centers. Glennan at one point confided to his assistants that "constant misunderstandings, accusations and arguments" had marked the first phase of NASA-JPL relations. JPL officials felt equally frustrated, with complaints that ranged from too much NASA interference in technical minutiae to the direction of the space program as a whole. The conflicts focused on four areas.[28]

First, the most basic problem was what role JPL would play in NASA. Did the laboratory really fit inside, as Silverstein had assured Pickering? And how could JPL's skills best be put to use in balance with headquarters and the other centers? "You have at JPL an eager, able and enthusiastic group," Glennan told Caltech President DuBridge in August 1959. "Given unlimited funds, they would be happy to solve all of our problems." He cautioned DuBridge, however, "that everything in this field will not be done by Goddard, by JPL or any other single group." But having given the laboratory the impression it would operate from the inside, NASA had failed to follow through, the administrator admitted to his deputies. The Washington office had encouraged JPL to draw up long-range studies, such as the five-year plan, but then it had not attempted to formulate programs in response to them. Pickering had detailed some of his top staff members to headquarters, but, said Glennan, "we have failed to make a conscious effort to make JPL a real part of NASA management." Glennan wondered whether the inside approach had been wise or whether JPL should be treated like a special contractor, such as the Los Alamos laboratory of the AEC.[29]

JPL chafed under the programmatic, budgetary, and manpower

restrictions NASA imposed on it. The measure of autonomy JPL had enjoyed under the Army seemed neither possible nor desirable to the space agency. Perhaps the most irritating action was NASA's imposition of a ceiling limiting JPL to 2400 employees in 1959-1960. The laboratory understood budgetary limits, but the personnel curb seemed arbitrary to JPL officials. Laboratory employment had climbed to about 2650 in 1959, and when the Sergeant program was phased out in mid-1960, about 100 persons had to be terminated in addition to normal attrition. Headquarters defended the ceiling as a necessary outgrowth of its budgetary limits, and its desire to limit in-house activities and encourage contracting with industry. Pasadena and Washington remained at odds on the issue.[30]

JPL found some amelioration of lines of authority, however, during the last months before Glennan resigned in January 1961. Although the laboratory's technical activities on Ranger had made great strides during 1960, the project had been bogged down in organizational chaos. NASA headquarters had been reluctant either to decentralize authority or to set up a special project organization. Under the ad hoc arrangement that ensued, JPL, Marshall Space Flight Center, Lockheed, and the Air Force each had splinters of authority. Conflicts were bucked to a bickering, slow-moving coordination board for resolution. After most of 1960 was consumed in an organizational ordeal, Ranger was reorganized in January 1961 with Glennan's promulgation of a major organizational change in Management Instruction 4-1-1. The core of 4-1-1 was a Project Development Plan, which set up specific project organizations for NASA undertakings and spelled out the rights and duties of the NASA centers. The PDP procedure amplified an important agreement Caltech and JPL had reached with NASA in August 1960. Headquarters had explicitly agreed to give the laboratory a voice in the determination of its program and to allow JPL virtually free rein in technical matters unless major reprogramming was needed. The August understanding assumed major importance for JPL as an interpretation of its basic contract with NASA. It embodied the concept of "mutuality," i.e. that actions were to be undertaken after both JPL and NASA agreed; NASA would not issue unilateral directives. This agreement gave the laboratory much of the freedom it wanted; now it had to perform.[31]

Despite these improvements in relations, NASA cast an increasingly skeptical eye at JPL in a second area: its internal operations. The main problem, a NASA staff memo said, was "lack of full-time direction of a decisive nature." Another weakness, related to the first, was "lack of administrative discipline," particularly in the technical staff. NASA believed that the decisions made by top management were frequently upset by the directors of the technical divisions. JPL also lacked "effective financial management and procurement processes." George Green, the Caltech business manager, had agreed this problem existed and was working on corrective measures. Items of lesser importance included the lack of staff assistance to the director, imprecise lines of authority, and splits among the technical and nontechnical sides of the house. To a greater or lesser degree all these objections -- warranted or not -- would build over the next several years and eventually force JPL closer to headquarters' operating philosophy.[32]

Third, NASA began to show an attentiveness to the connection, or lack of it, between the laboratory and Caltech that had never interested the Army. Glennan later termed the overhead fee the Institute had received for managing the laboratory in the Army days "a bribe." He felt significant advantages could accrue from having a laboratory aligned with Caltech, but he also wanted to see some tangible benefits. Adopting the voice of one college president confiding in another, Glennan praised DuBridge's expressed "determination to bring the 'resources' of the Caltech campus into a more positive and productive relationship with JPL. This seems to me to be the very essence of the reasoning behind the involvement of an educational institution of high quality in the management and operation of an activity such as JPL." One perhaps unexpected byproduct of JPL's joining the civilian space effort was the opportunity, and the expectation, of greater campus involvement.[33]

Fourth, JPL and NASA continued to differ over the pace of the space program. The agency's budget had climbed to $915 million in fiscal year 1961, and by January 1961 it had outlined a ten-year plan that forecast much of the American space program, including sending a man to the moon, though only in the 1970s. NASA had continually rubbed against the administration. Eisenhower was still chasing the illusory balanced budget, but he also appeared sincerely to believe that the United States was not racing the Russians but engaging in "a scholarly exploration of space." His science advisor, George Kistiakowsky, cast a baleful eye over the diffuse NASA program and observed that the agency "did not have a space program but only one to feed the many hungry NASA mouths."[34]

JPL in 1960 was one of those feeling hungry. When the laboratory had to terminate nearly 100 persons in May 1960 and the Ranger budget fell short, Pickering sent a plaintive letter to Glennan. Ranger reminded Pickering of Vega. "It appears that once again we are saddled with an interim project which will gradually slip to the point where it is no longer justified and must be canceled," he fretted. More than fourteen months had passed since JPL had conducted a space experiment, he continued, and at least eleven months would elapse before the first Ranger flight. JPL needed to carry projects to completion to demonstrate, and to keep, its competence. "We would like to believe that we are doing something important for the Nation," Pickering said, but it was hard to maintain morale without support from headquarters. Glennan explained the budgetary problems he faced, reassured Pickering about the importance of Ranger, and called on him to provide the leadership to maintain morale.[35]

But to Pickering and many of his subordinates, the misfortunes of Ranger seemed too representative of more general NASA woes. JPL conducted its research with one eye on the Cold War clock. "It is the U.S. against Russia," said Pickering in early 1960, "and its most important campaign is being fought far out in the empty reaches of space." But if one asked "'Do we now have a space program?' the answer must be "No.'" James Killian had listed space objectives as, in order, scientific, commercial, military, and human. Pickering felt he had omitted the most important objective: "to equal or exceed the achievements of Russia in space." The United States had to do this to maintain national prestige, nor solely for reasons of pride, but for "very hard-headed economic reasons."[36]

JPL thus closed its first two years under NASA with much the same feeling of frustration that it had entered the relationship. Some institutional arrangements had been clarified, at least temporarily, and aspects of the laboratory's program had been settled. But JPL still thirsted for the first major triumph in space, and it looked eagerly to the new administration in Washington to provide the impetus it wanted. Ironically, as the laboratory approached its first Ranger flights in 1961, its own shortcomings would soon become apparent, with grave implications for the space program and the health of the Jet Propulsion Laboratory.

FOOTNOTES

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3. Pickering to Medaris, May 13, 1958, Medaris to Jack Froehlich, May 14, 1958, roll 614-218, JPLVC.

4. Robert Parks to Froehlich, Aug. 8, 1958, roll 614-218, JPLVC.

5. McGarrity to Pickering, June 20, 1958; author's interview with Cliff I. Cummings, Arlington, Virginia, April 27, 1976; J. H. Wilson interview with Homer Stewart, Sept. 20, 1972, JPLHF 3-646.

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30. Glennan to Dryden, et al., Oct. 19, 1959, box 16, acc. 70A5793, RG 255, WNRC; Pickering to Glennan, May 17, 1960, JPLHF 3-947.

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34. Kistiakowsky, A Scientist at the White House, pp. 100, 182, 173, 114.

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